SunRISE

Sun Radio Interferometer Space Experiment

Revealing How Energetic Particles are Accelerated and Released into Interplanetary Space

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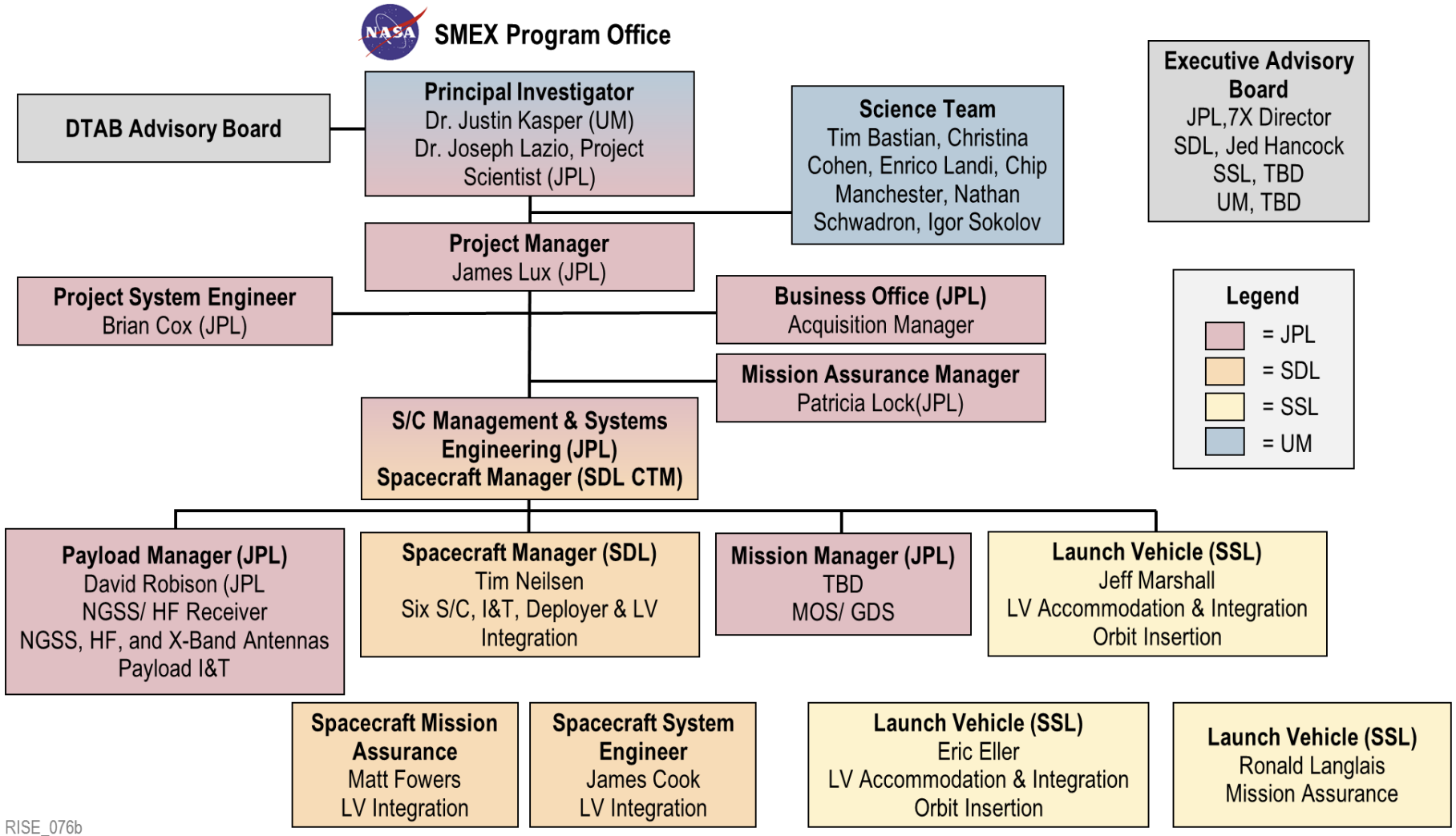
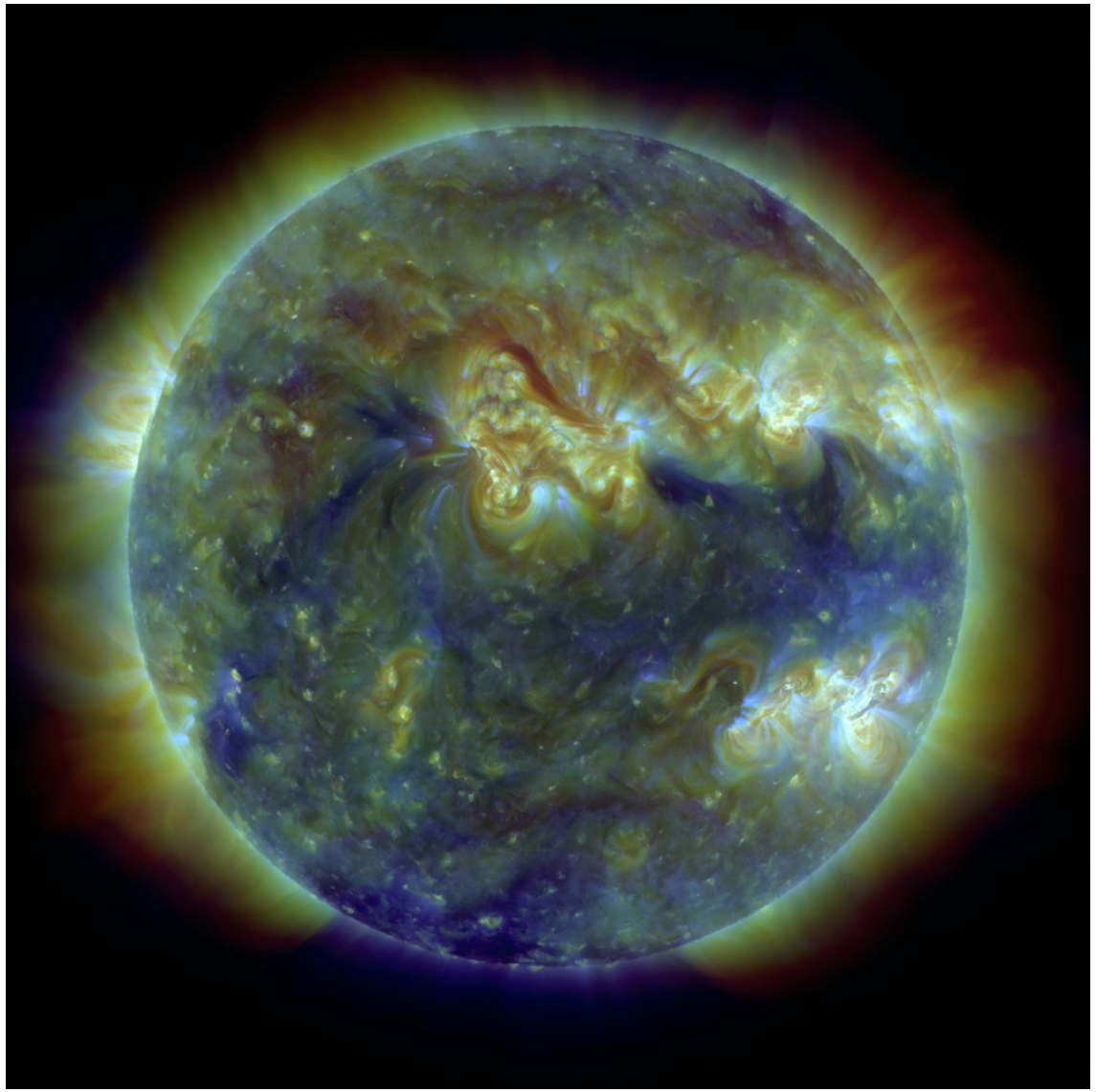
The SunRISE Team



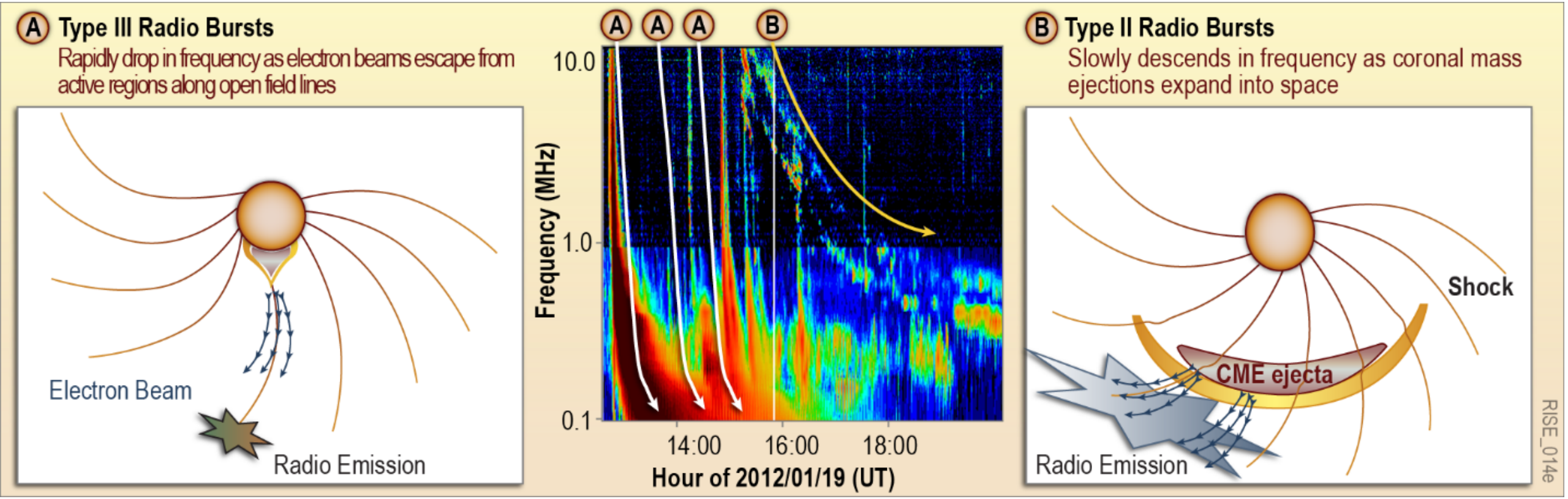
Particle Acceleration

- One of the greatest scientific challenges in Heliophysics is to understand how magnetic energy in the corona is converted into intense relativistic particle radiation and how this radiation propagates into interplanetary space
- Flares and coronal mass ejections (CMEs)
- CMEs responsible for most intense SEP events, with order 10% of kinetic energy converted into high energy SEPs

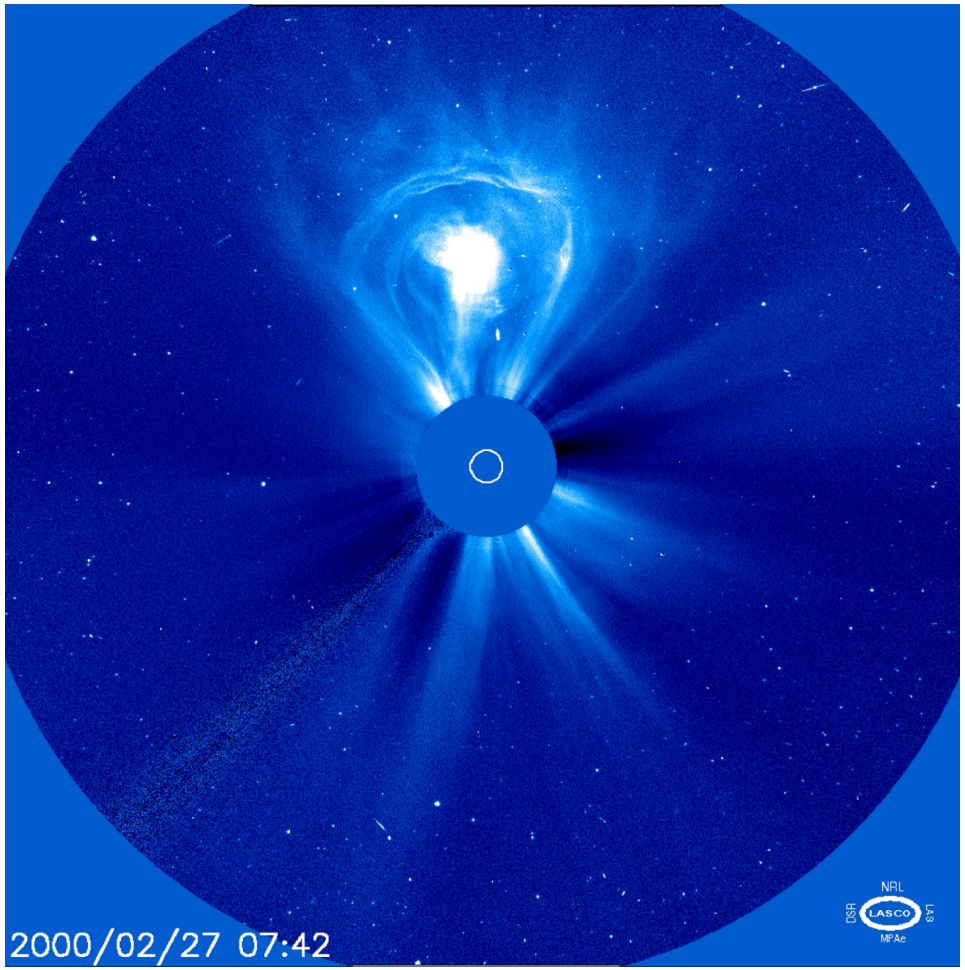


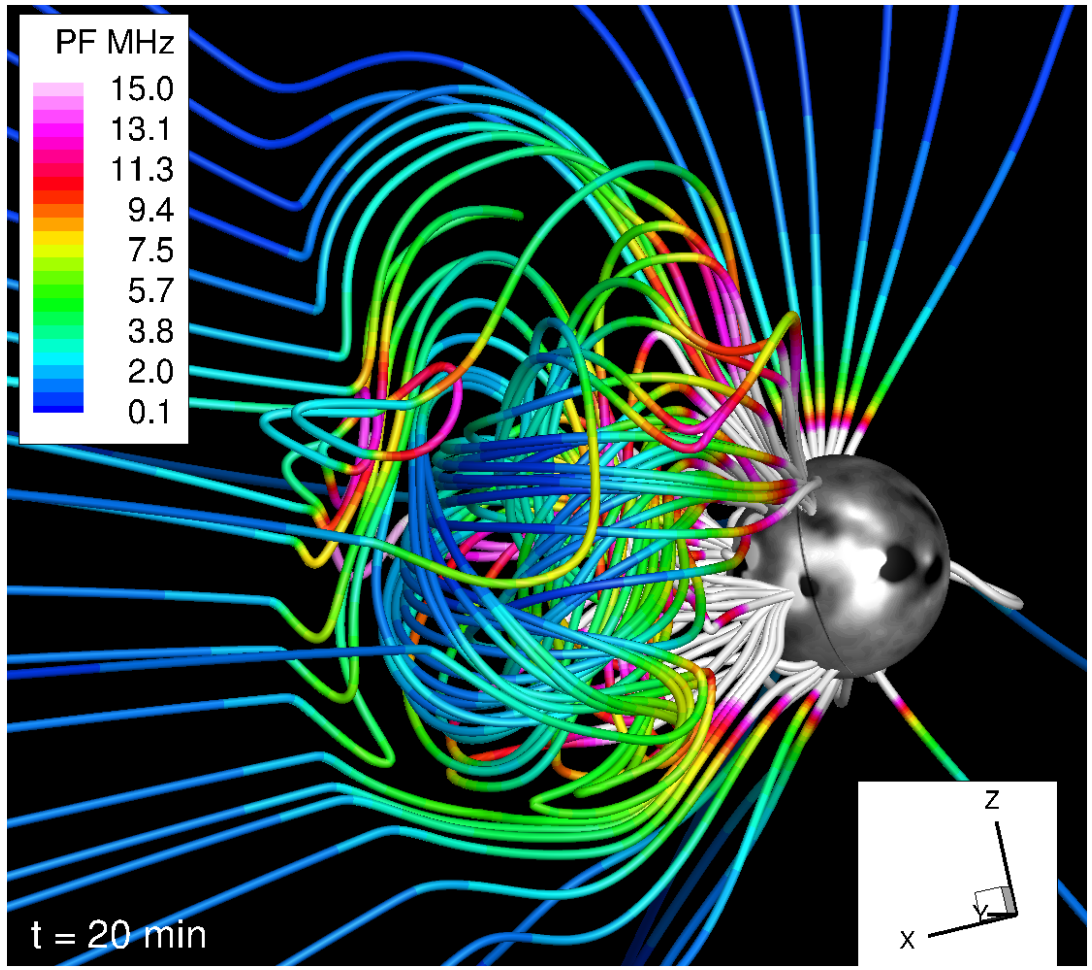
Coherent solar radio bursts

$$f_p = 8.98\ kHz\sqrt{n_e/(1\ cm^{-3})}\,, f_{obs} = (f_p, 2f_p)$$

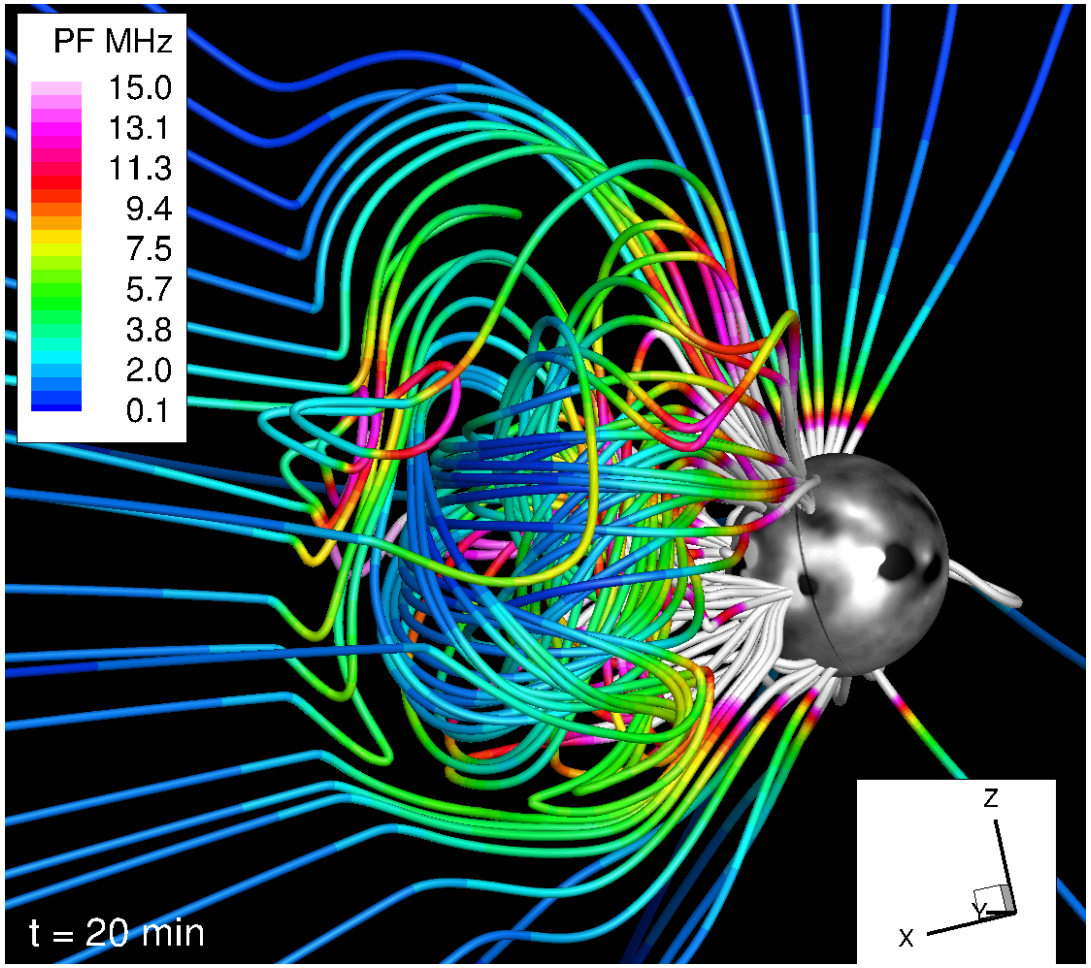


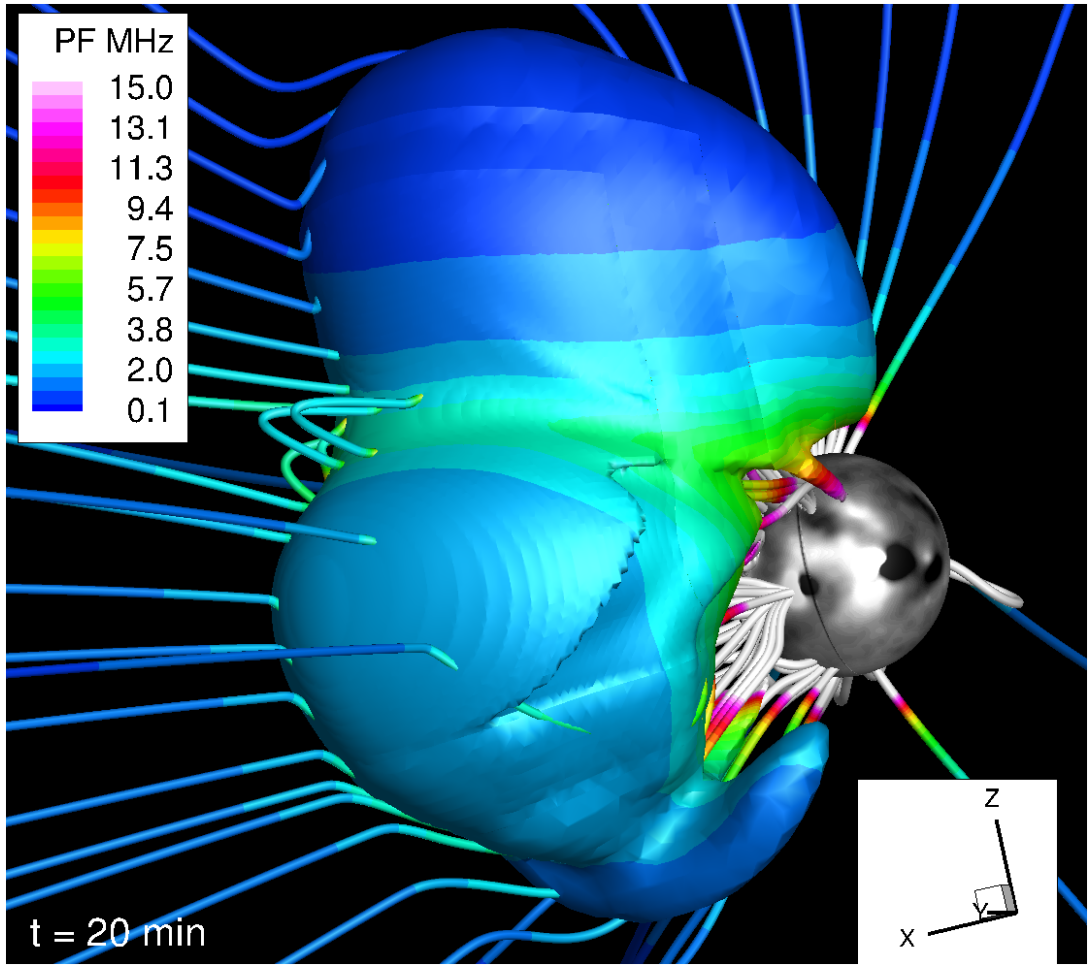
Anatomy of a coronal mass ejection (CME)





Anatomy of a CME

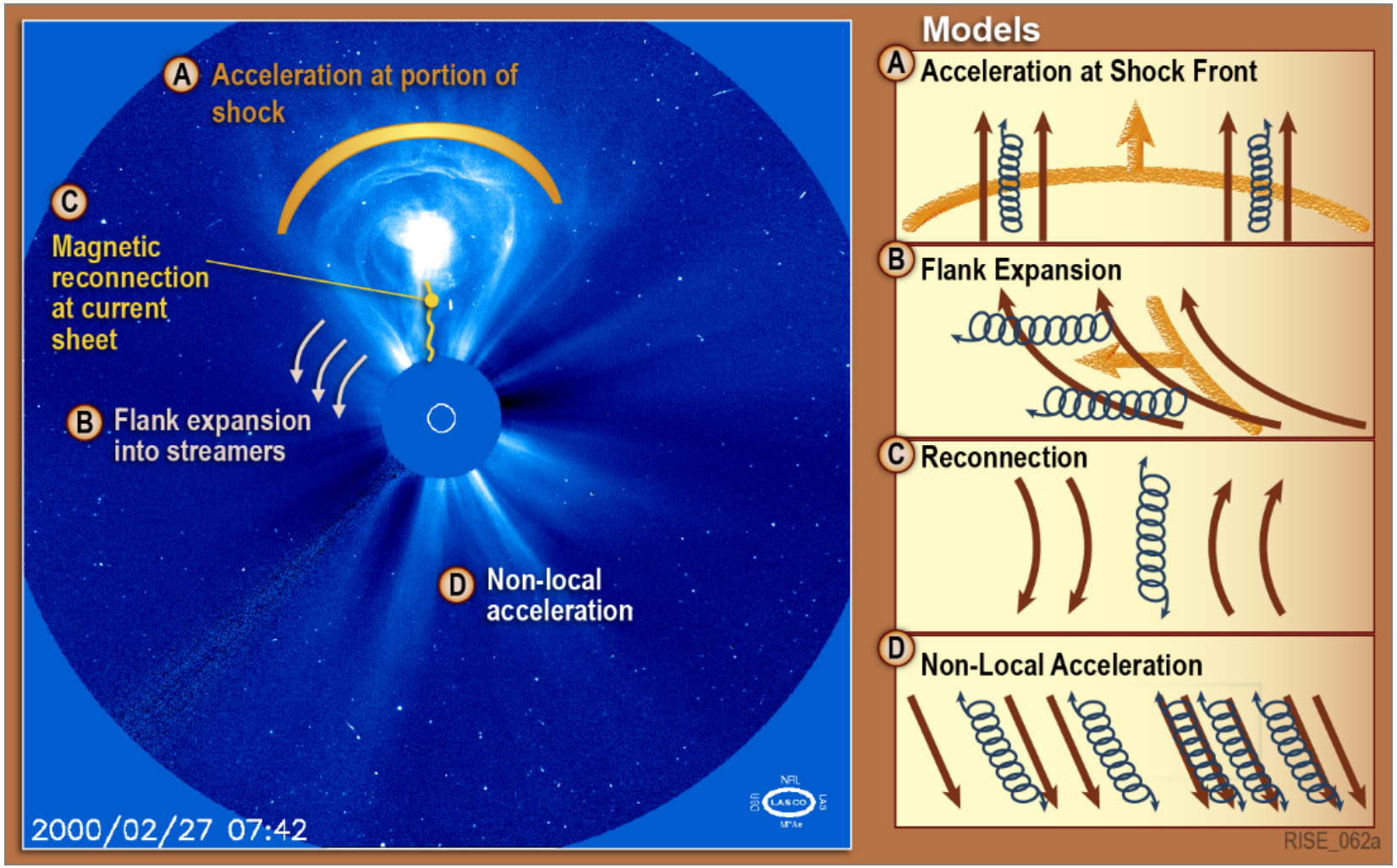




Discriminate competing hypotheses for the source mechanism of CME-associated SEPs by measuring the location and distribution of Type II radio emission relative to expanding CMEs 2–20 Rs from the Sun, where the most intense acceleration occurs.

SunRISE Objective 1

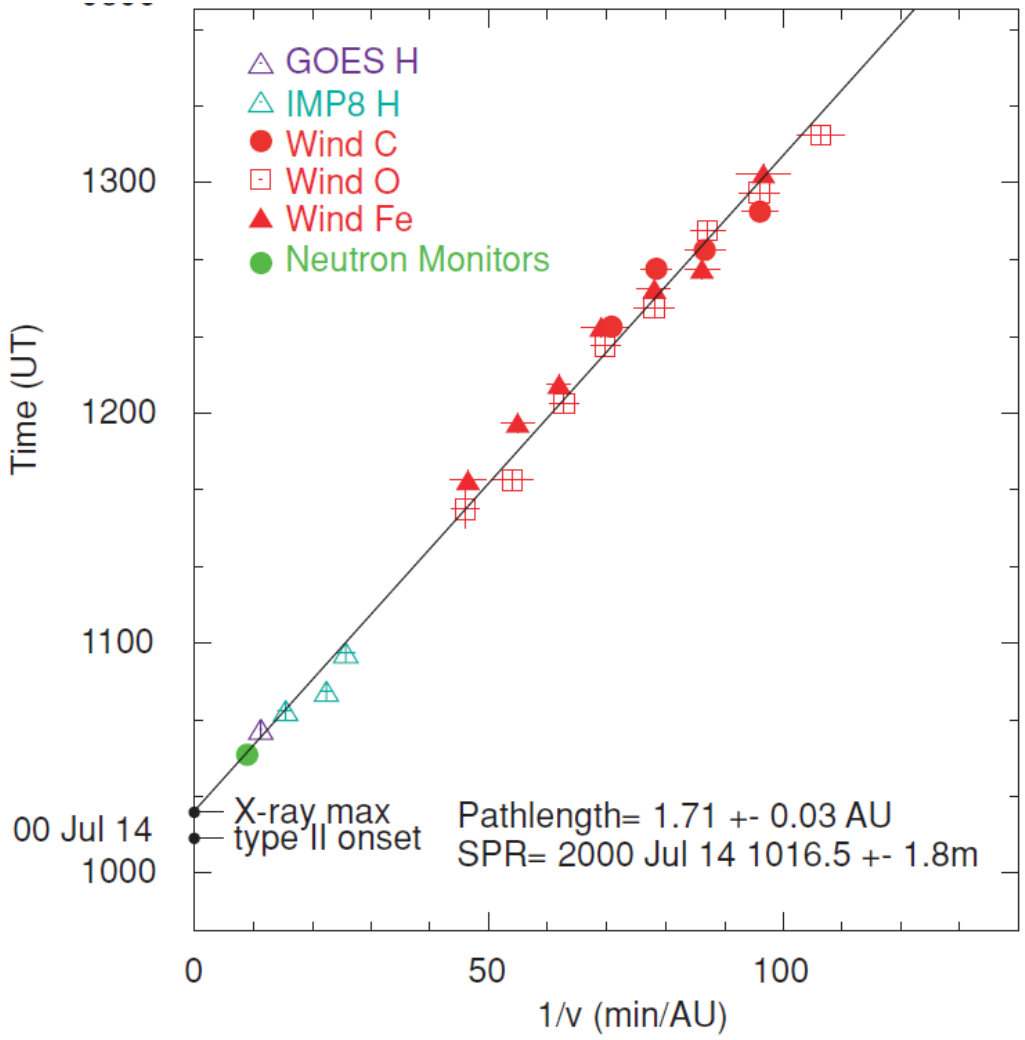
Categories of theories of ion and electron SEP acceleration by CMEs



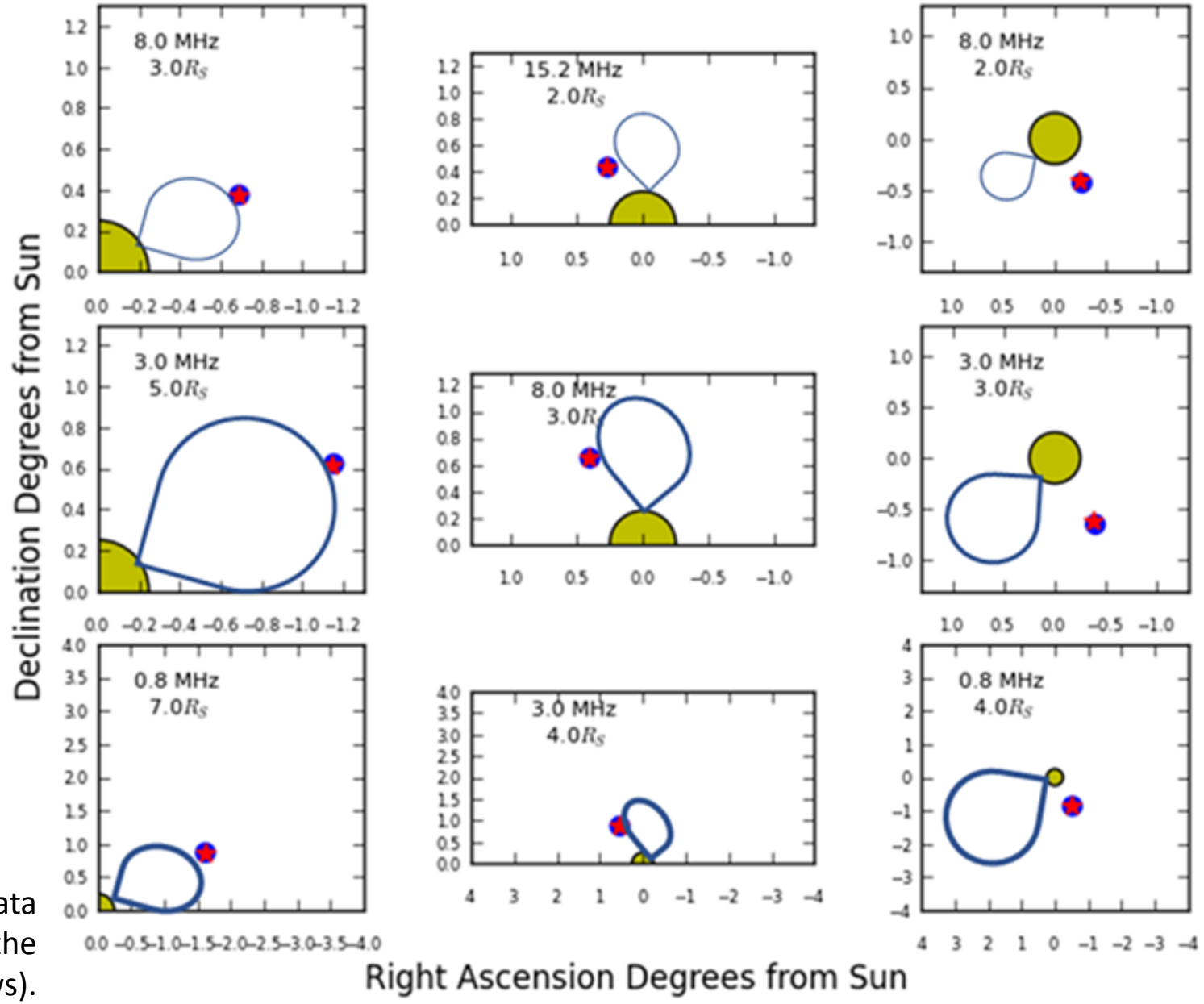
(A) shock and compression acceleration in front of a CME as it expands outwards into the corona (Tylka et al. 2005,; 2006; Tylka and & Lee 2006a, 2006b); (B) shock and compression acceleration on the flanks of a CME as it expands laterally into quiet streamers (Schwadron et al. 2015), (C) magnetic reconnection at current sheets formed behind the ejecta (Forbes and & Isenberg 1991; Forbes and & Priest 1995); and (D) a non-local process occurring as plasma is diverted and compressed by the expanding filament (e.g., Fisk and & Gloeckler 2008; Chotoo et al. 2000; Chen et al. 2015; Drake and & Swisdak 2012; Zank et al. 2015).

The SEP – DH Type II Burst Connection

- All major SEP events (NOAA classification > 10 pfu above 10 Mev) are proceeded by a DH Type II burst
- When timing is possible arrival time of SEPs at Earth vs speed can be solved for SEP release time and height above Sun
- Generally SEP release occurs 10-20 minutes after DH Type II burst starts



O1.1: Is shock/compression, magnetic reconnection, or non-local acceleration the source of initial electron acceleration and associated Type II radio bursts?

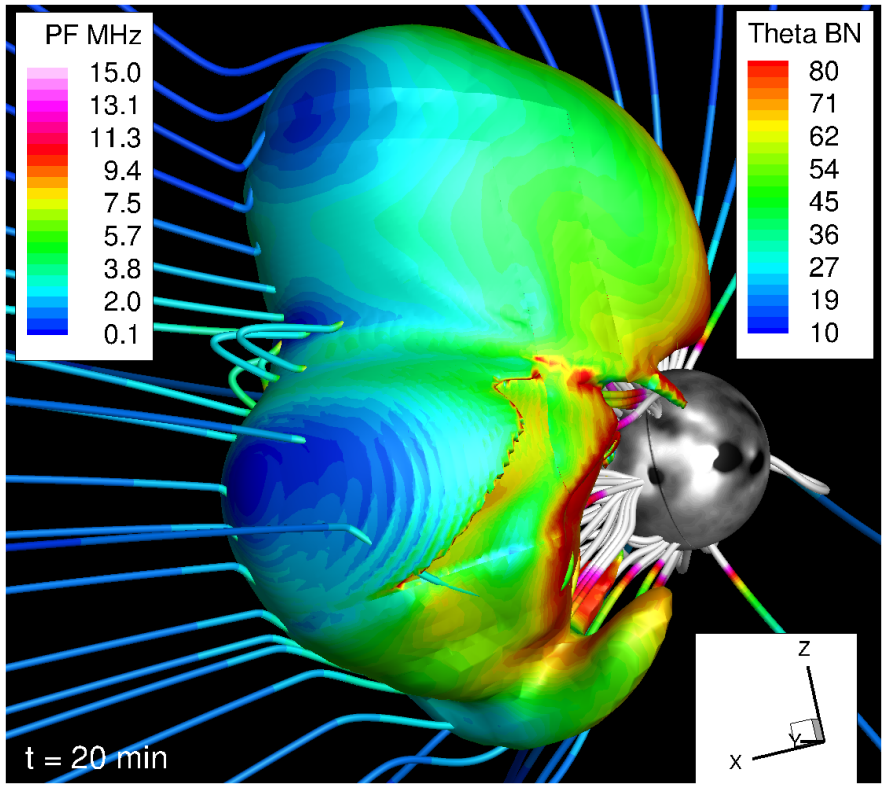


End-to-end simulations through working SunRISE data processing pipeline for three location scenarios (the three columns) increasing time (descending rows).
Blue = truth, **Red** = measured location

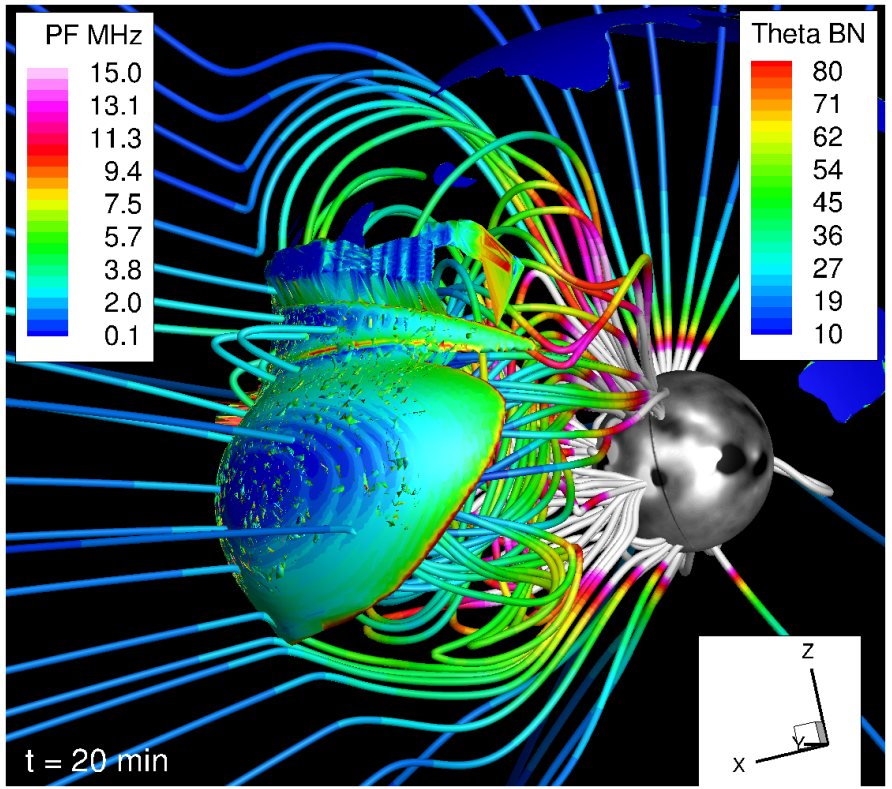
O1.2: What physical properties of CMEs and the upstream corona are correlated with Type II bursts?

O1.3: Are CMEs with Type II bursts but no SEPs due to the burst locations not being connected to the interplanetary observer?

θ_{Bn} surrounding CME



θ_{Bn} just at shock surface



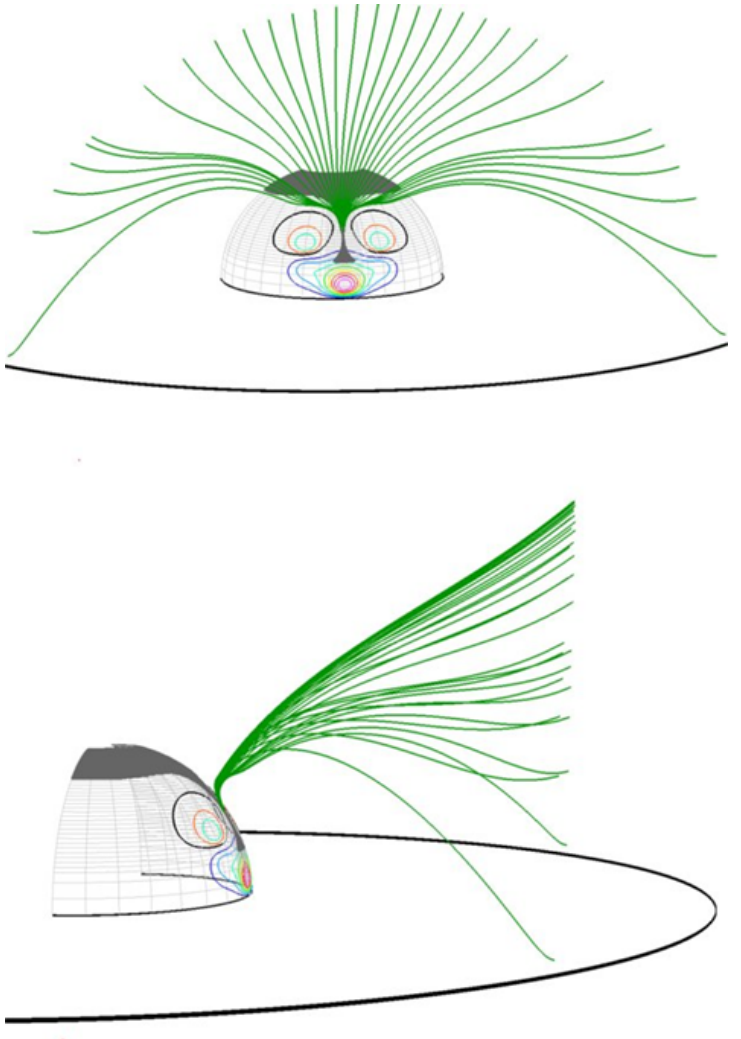
We will correlate SunRISE localizations with context images and with 3D MHD simulations. UM AWESoM multifluid CME simulation shown here (Manchester)

Determine if a broad magnetic connection between active regions and interplanetary space is responsible for the wide longitudinal extent of some flare and CME SEPs by imaging the field lines traced by Type III bursts from 2–20 Rs.

SunRISE Objective 2

The puzzling reach of SEPs into the heliosphere

- Interplanetary SEPs are *often* linked to how well the spacecraft is magnetically connected to the source
  - Time to peak flux, magnitude of flux, energy dispersion
  - If well connected along spiral, rapid rise in flux to high intensity at spacecraft; if poorly connected slow rise, weaker flux
- Observations by spacecraft well-separated in longitude (Helios, STEREO) have produced SEPs seen across large range in longitude
  - 3 November 2011 (Richardson et al. 2014; Cohen 2016)
  - About 1/3 of SEP events at Earth had a source on the far side of the Sun!
- Much too large to be explained by random walk of field lines in heliosphere due to random walk (10° maximum, e.g. Wiedenbeck et al. 2013, Giacalone & Jokipii 2012; Cohen 2016)
- New theoretical framework for coronal field and origin of slow solar wind called seperatrix web allows small regions on Sun to map into broad region in heliosphere (Antiochos et al. 2012)

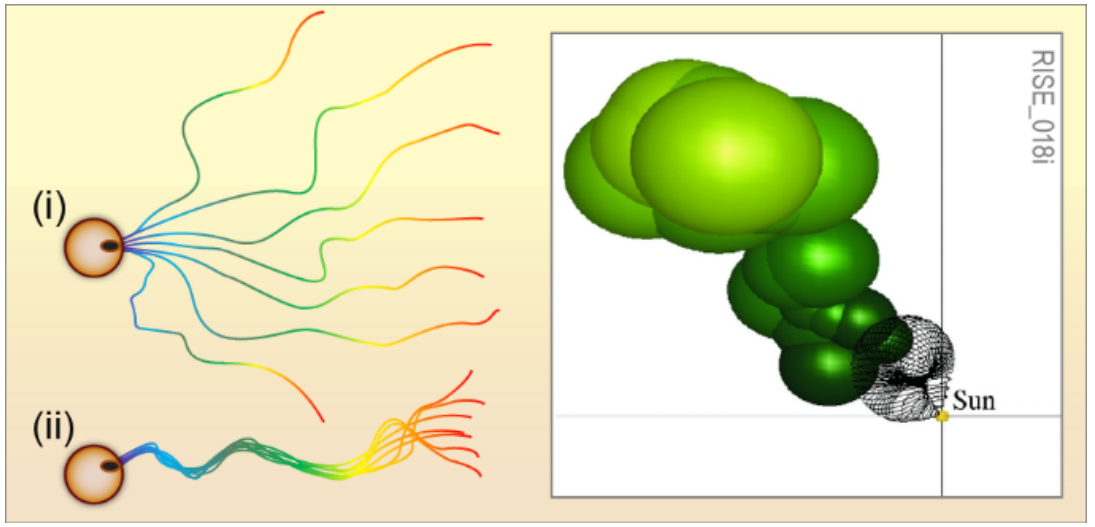


Antiochos et al. 2012

Mapping field lines

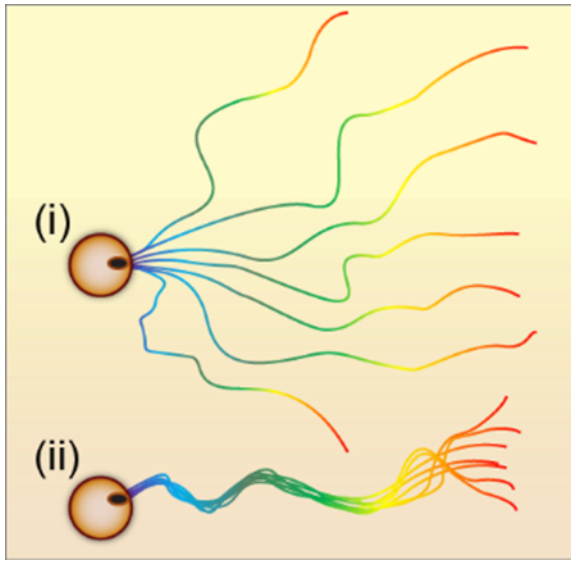
O2.1: What is the spatial and temporal variation of the magnetic connection between an active region and the heliosphere in space and time?

O2.2: How well is the observed magnetic topology reproduced by coronal simulations?

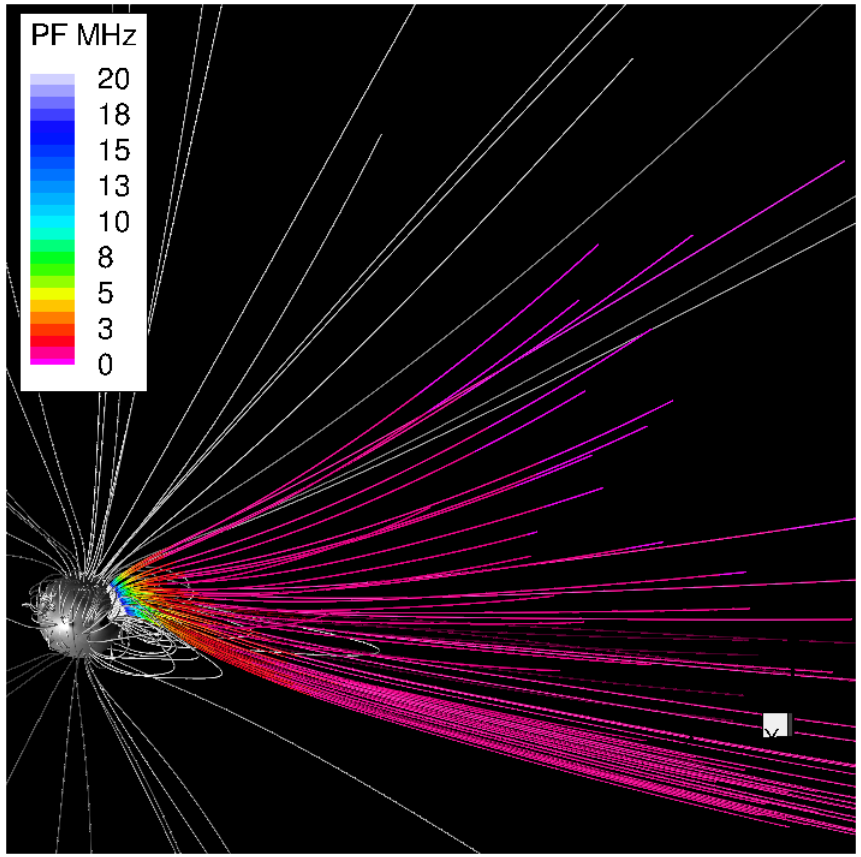


Credit: Public Records Office Victoria

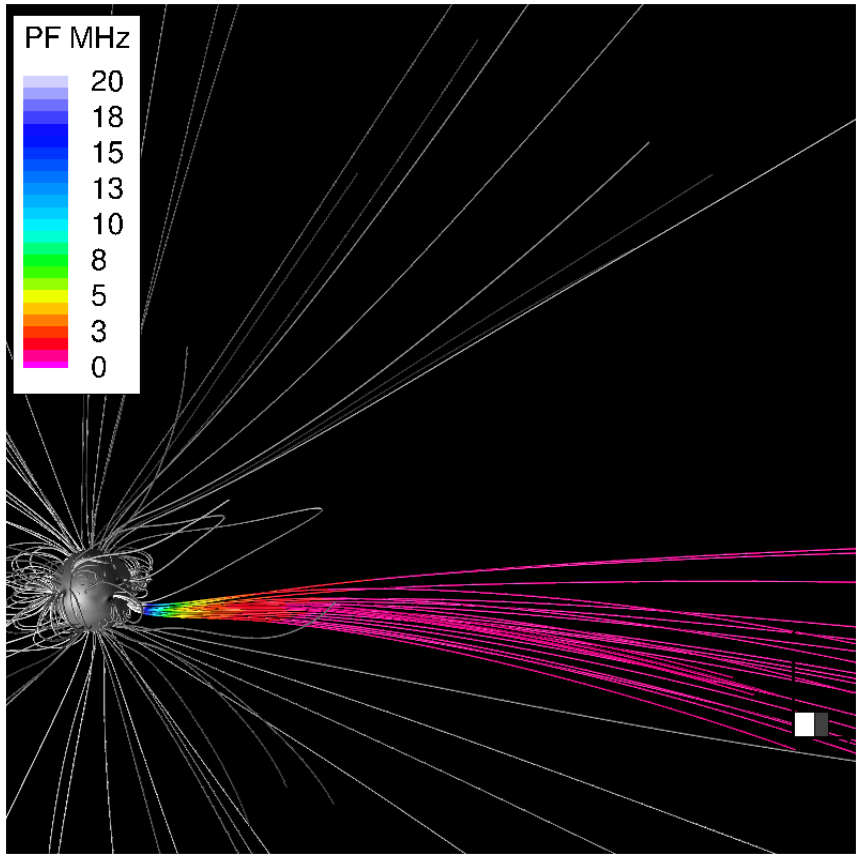
Simulated observations and closure with model

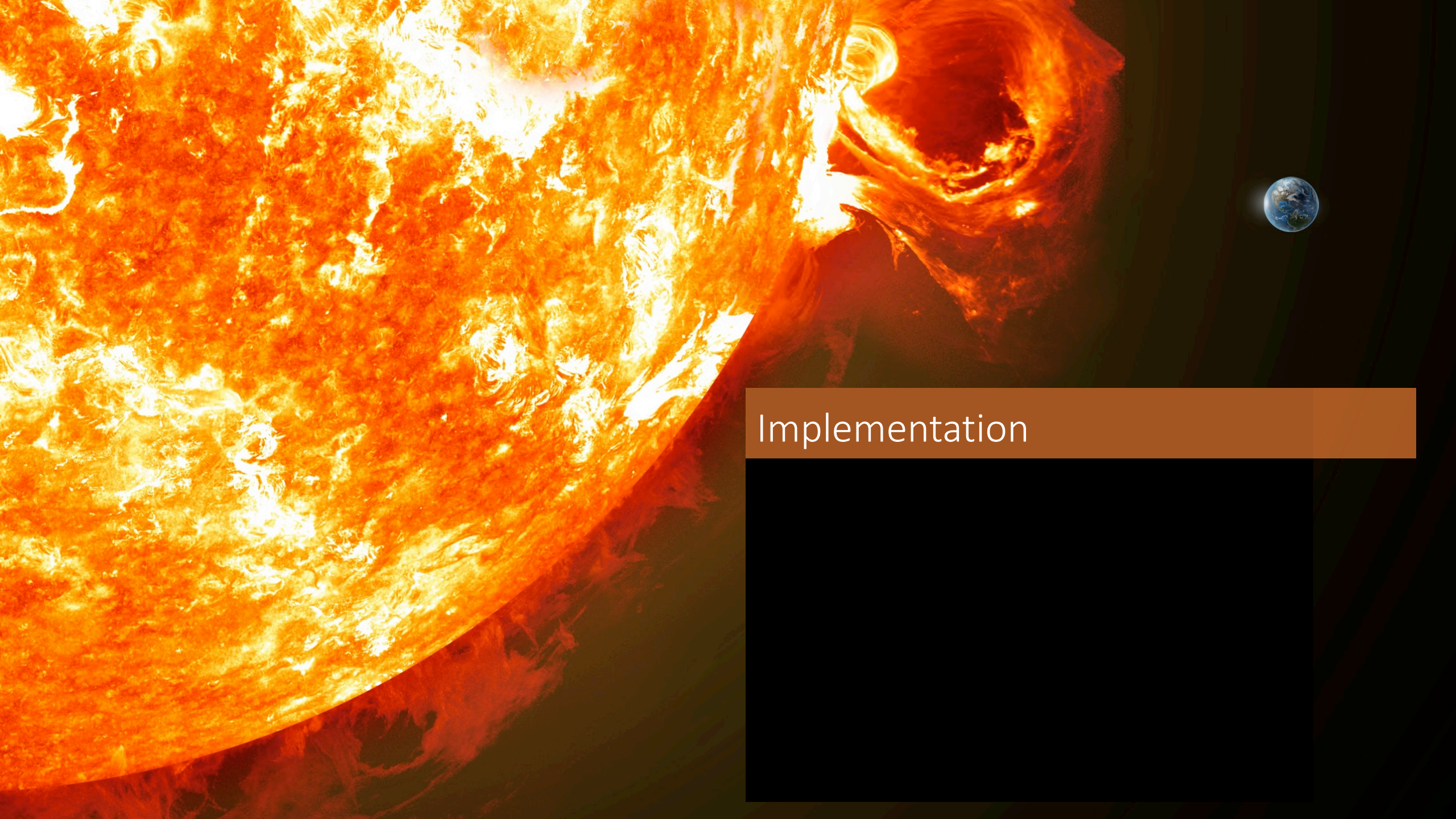


Seperatrix-web Scenario (i)

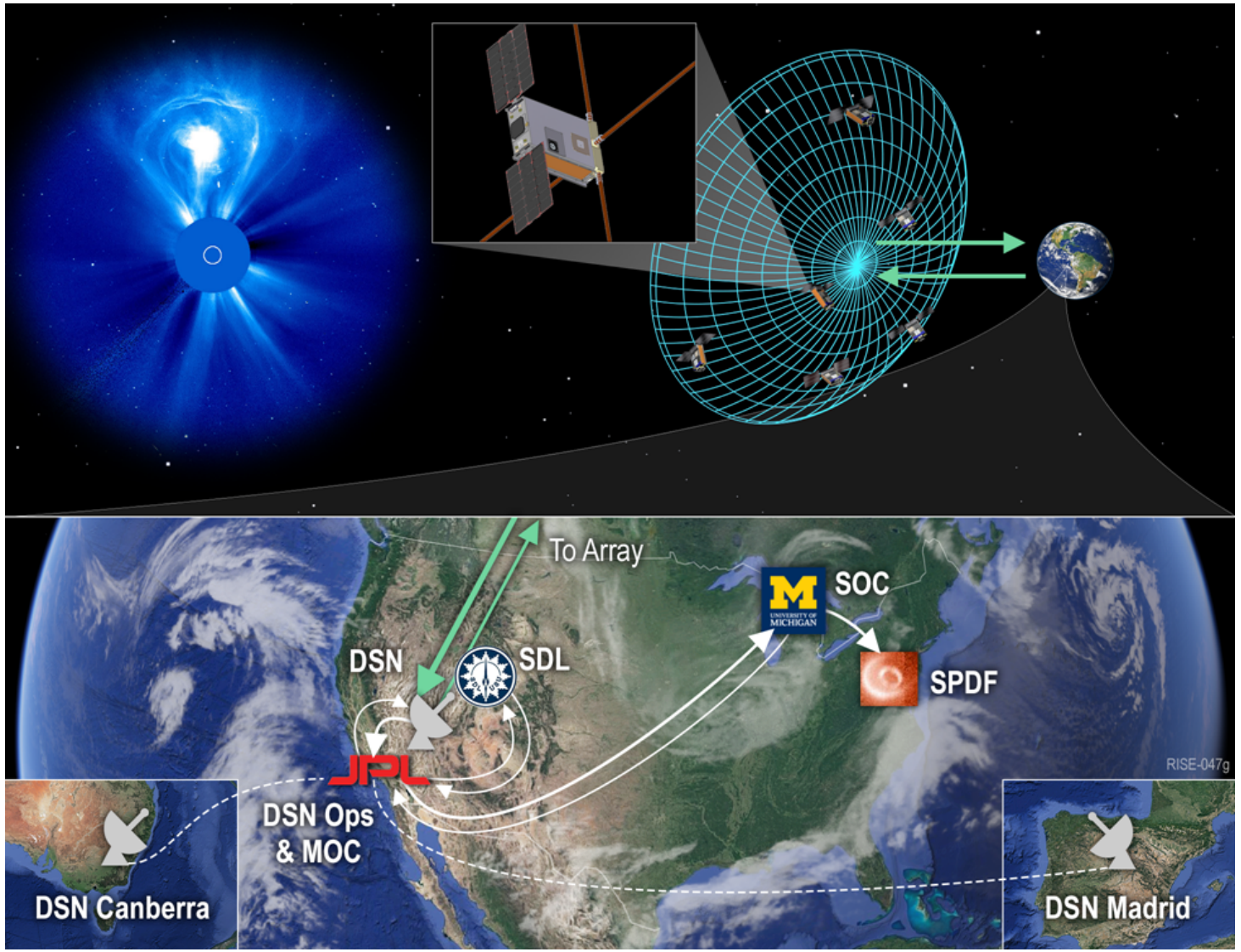


Random walk Scenario (ii)



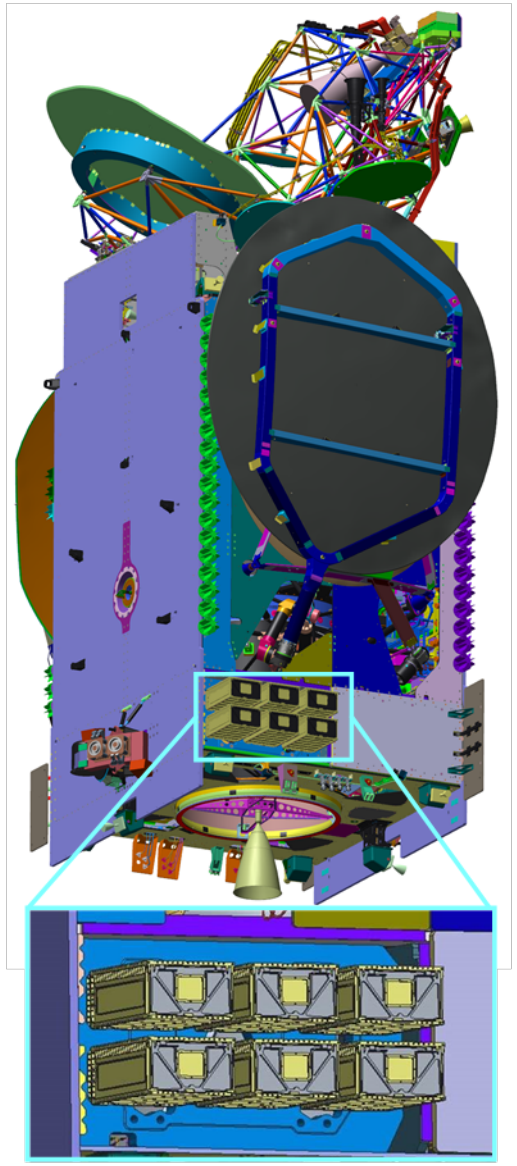


Implementation

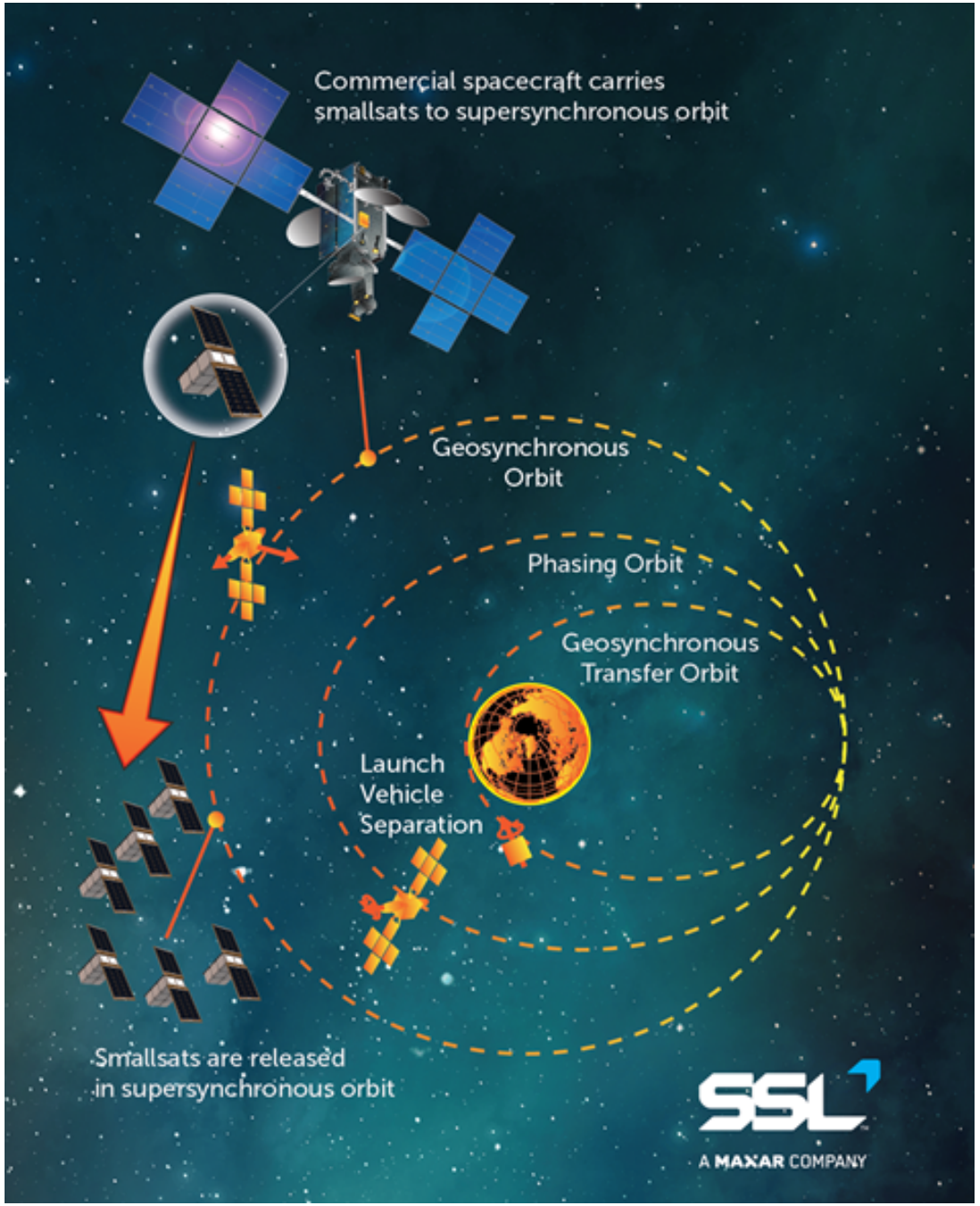


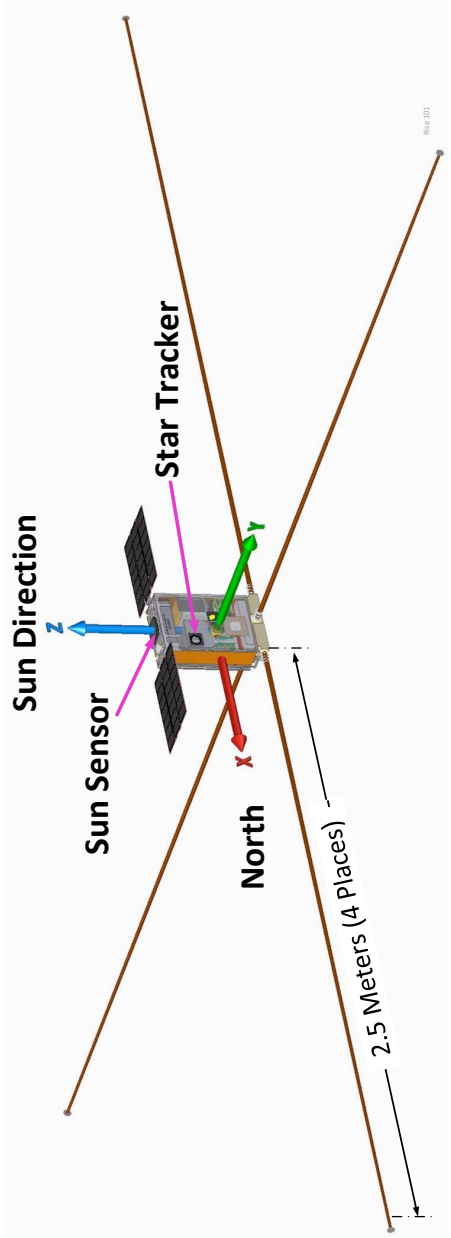
IMPLEMENTATION

- First interferometer in space, first decametric-hectometric (DH) imaging
- Loose formation of six 6U form factor CubeSats in 10 km sphere
- GEO Plus Orbit (25 hour orbit period)
- DH radio receiver (0.1 – 20 MHz) with crossed 3m dipole antennas
- Data collection in series of $500\mu s$ bursts every $0.1s$, select from 4096 frequencies
- Relative position knowledge to within 3 m and timing to ns
- Direct delivery to GEO+ as secondary payload
- 3GB of data produced per week, all downloaded no bursts or triggers
- March 2022 Launch Readiness, Six month Phase E



SSL Payload Orbital Delivery System (PODS)



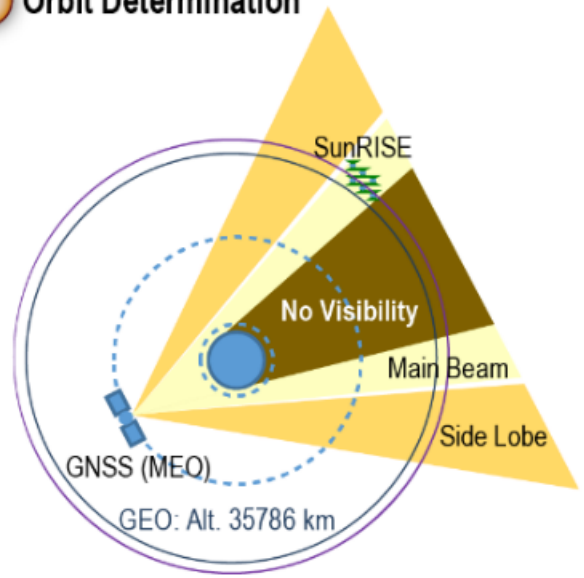


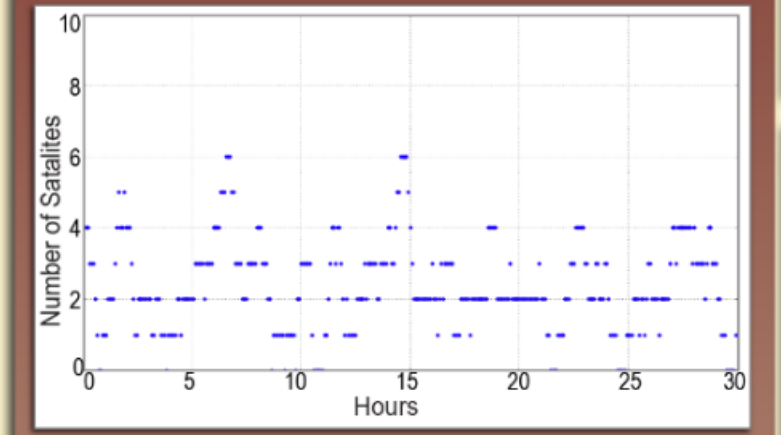
Summary

- SunRISE will do amazing, first of its kind science in a MoO budget
- Our driving objectives are well defined and will significantly advance our understanding of SEP acceleration and transport
  - Localize DH Type II bursts relative to erupting CMEs
  - Trace the magnetic connection between active regions and interplanetary space
- Implementation is straightforward and makes use of three key advances
  - CubeSat form factor and technology, especially DHFR predecessor
  - GPS for both location and timing
  - Delivery to GEO+ orbit by Space Systems Loral
- We hope you are excited about both our science and the many other applications for the SunRISE dataset once it is on the ground and we look for your support from selection this winter to launch in 2022

Backup Material

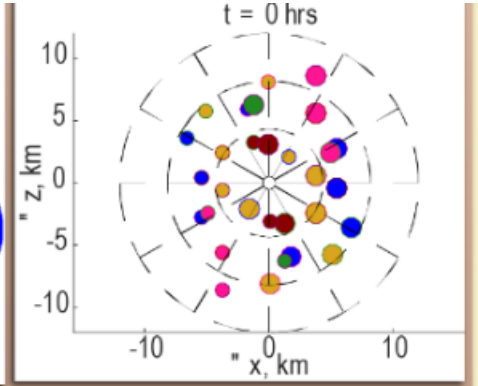
F Orbit Determination

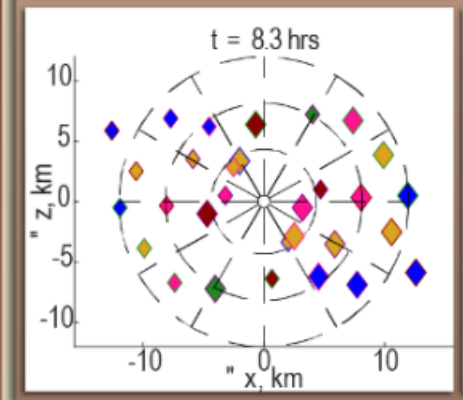


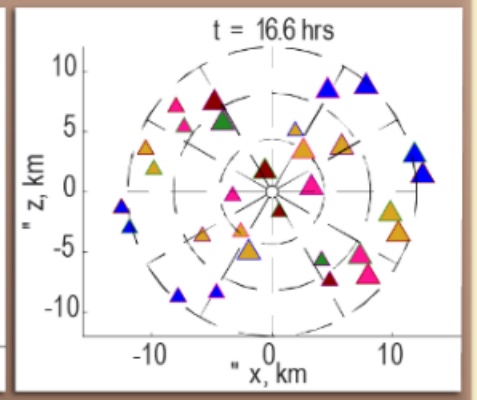


SunRISE Science Navigation Uncertainty	
Absolute position (m)	2
Absolute velocity (mm/s)	0.2
Relative position (m)	2*

*Measurement errors correlated







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E Two-Week Station-Keeping Cycle